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To cite this article: S D Filonov *et al* 2019 *J. Phys.: Conf. Ser.* **1210** 012047

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Method for loading cargo trucks using two-dimensional packing algorithms

S D Filonov, K A Aksyonov and V N Kruglov

Ural Federal University, Ekaterinburg, Russia

s.d.filonov@urfu.ru

Abstract. The paper describes the method for optimization of loading cargo trucks using two-dimensional packing algorithms. The point of this method is to reduce loading cargo problem to two-dimensional packing problem. This problem can be solved by using of various algorithms. There is analysis of several algorithms that are most often used in practical calculations of objects distribution in 2D space in this paper. The object of this study is transport of the metal processing company and its products (cargo). PHP programming language, MySQL database, and Apache web server are used to create client application. The interface developed using HTML5, CSS and javascript.

1. Introduction

Cargo distribution for trucks is a combinatorial optimization problem. Solving such tasks is a quite common problem and depends on conditions [1]. In this case, it is necessary to distribute packages of various sizes with products of the metal processing company [2].

This task involves calculating free space in the cargo platform and cargo distribution in it. To simplify this problem, it is proposed to reduce calculations to distribution of cargo packages in two-dimensional space.

Necessary calculations are realized within the developing web-application for optimizing manufactory logistics [3]. According to this, we will achieve quicker preparation works on cargo packing and trucks choice.

2. Theory

The enterprise receives multiple orders for parts of various sizes. Products distribution depends on weight of parts and carrying capacity of a transport unit. An additional condition is loading parts from one order into one truck. However, main task is alike to three-dimensional (3D) packing problem [4] – it is a distribution 3D objects into some limited space.

The objective function in this optimization process is to minimize free space and remaining load capacity in each of transport units used for cargo transportation.

Especially in case for 3D packing there are many methods for different conditions. Because of the diverse parts set for loading, finding an optimal packing for this cargo using methods that operate objects in 3D space will require large computational resources and, in addition, will be associated with the development of more complicated algorithms. To simplify this process, it was decided to split it into two stages.

At first stage, parts of the same type are grouped together. Within each group, an optimal variant of combining the parts into one or more bundles along one axis is determined so that builded bundle is placed in transport unit along one of its axes. By the end of this stage we get a set of parts bundles, each of which fills truck on one same axis.



At second stage, bundles are distributed along two other axes (which were not objects of optimization in previous step) of transport unit. In this way, 3D packing problem reduces to two-dimensional (2D) packing, because one axis of cargo can now be ignored.

2D packing [5] is a simpler task for automated calculations and there are many methods and algorithms to analyse this. Let us consider some of them in our case.

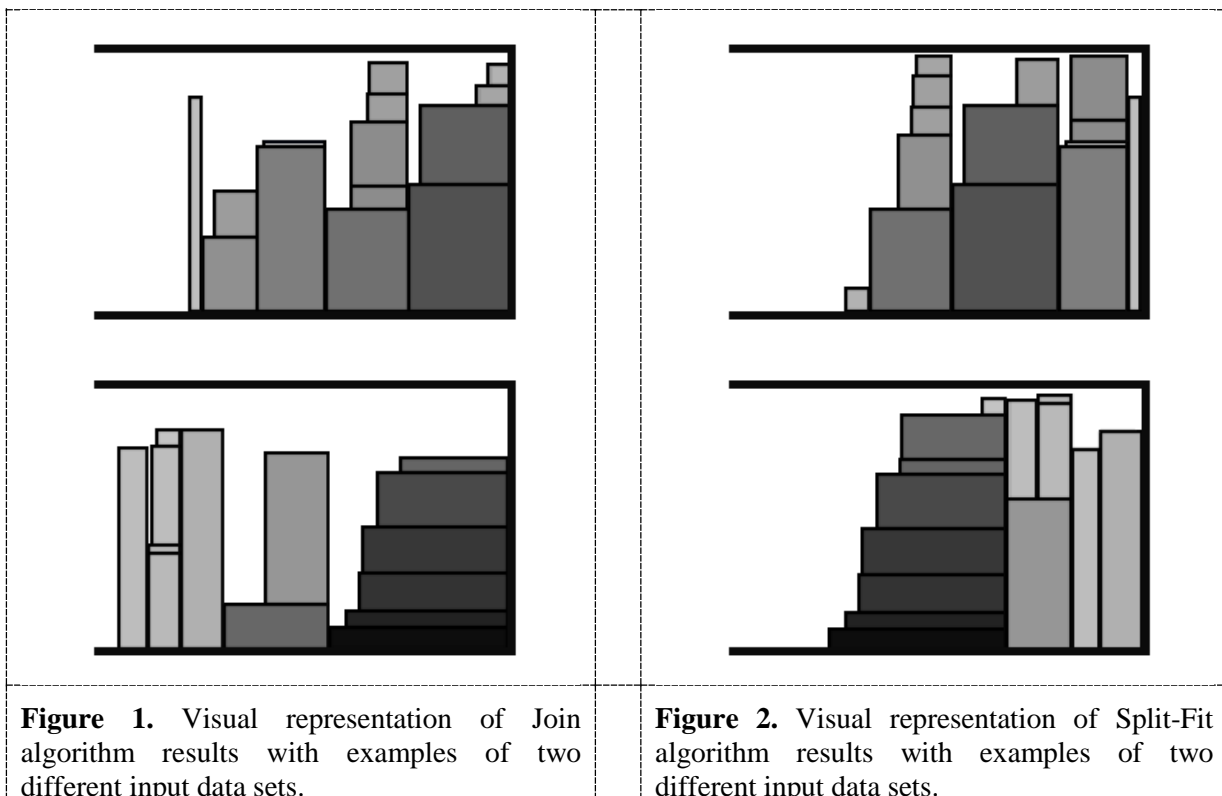
3. Algorithms for solving 2d packing problems

Several algorithms that are most often used in practical calculations of objects distribution in 2D space were chosen for analysis.

Next logical step after the first stage is Join algorithm [6]. Input data is sorted by non-increasing height and combined into pairs according to two conditions: difference in height of one pair does not exceed a certain percentage (10% for our case, because of products diversity) so that large loads are not combined with too small; total width of one pair does not exceed a width of the cargo platform. Further, received pairs and other remaining products are packed using the First-Fit Decreasing Height (FFDH) algorithm.

Input data is sorted by non-increasing width using FFDH algorithm. The widest load is placed into far corner of the cargo platform. Others are placed from top to bottom on the first load, while height allows that. If product does not fit in height, it is moved to the next level in width. Possibility of placing product at previous levels in remaining free space is checked for each next load.

Split-Fit algorithm [7] is considered as an alternative to Join algorithm. First step is to divide all products into two groups: above half height of the cargo platform and lower. From the first group, we separately take products higher than $2/3$ of the platform. The packages selected in this way are first loaded using FFDH algorithm. Then, remainings of the second group that are above half the height, but less than $2/3$, are loaded. All other products are loaded with the same FFDH algorithm, but first try to place them into free space left at the previous level (that is $1/3$ of the cargo platform height).



In results of this examples we can see that the Split-Fit algorithm packed products more tightly, however it is good for use only with large packages. Because of the products diversity, in case of order

with a lot of small items we should use Join algorithm. That is why it was decided to use both algorithms in developed application and leave it for operator to decide which result to apply in any case.

4. Realization

For optimizing logistics of the enterprise, a web application is developed [8] using PHP programming language (version above 7.0), MySQL database (at least version 5) and BoltCMS content management system.

Application utilizing of chosen algorithms is made using Javascript.

As basis for simulation modeling there is chosen multi-agent process model of resource conversion and its software that included automated system for metallurgical production and BPsim complex. Multi-agent simulation is used to model logistics processes of the enterprise.

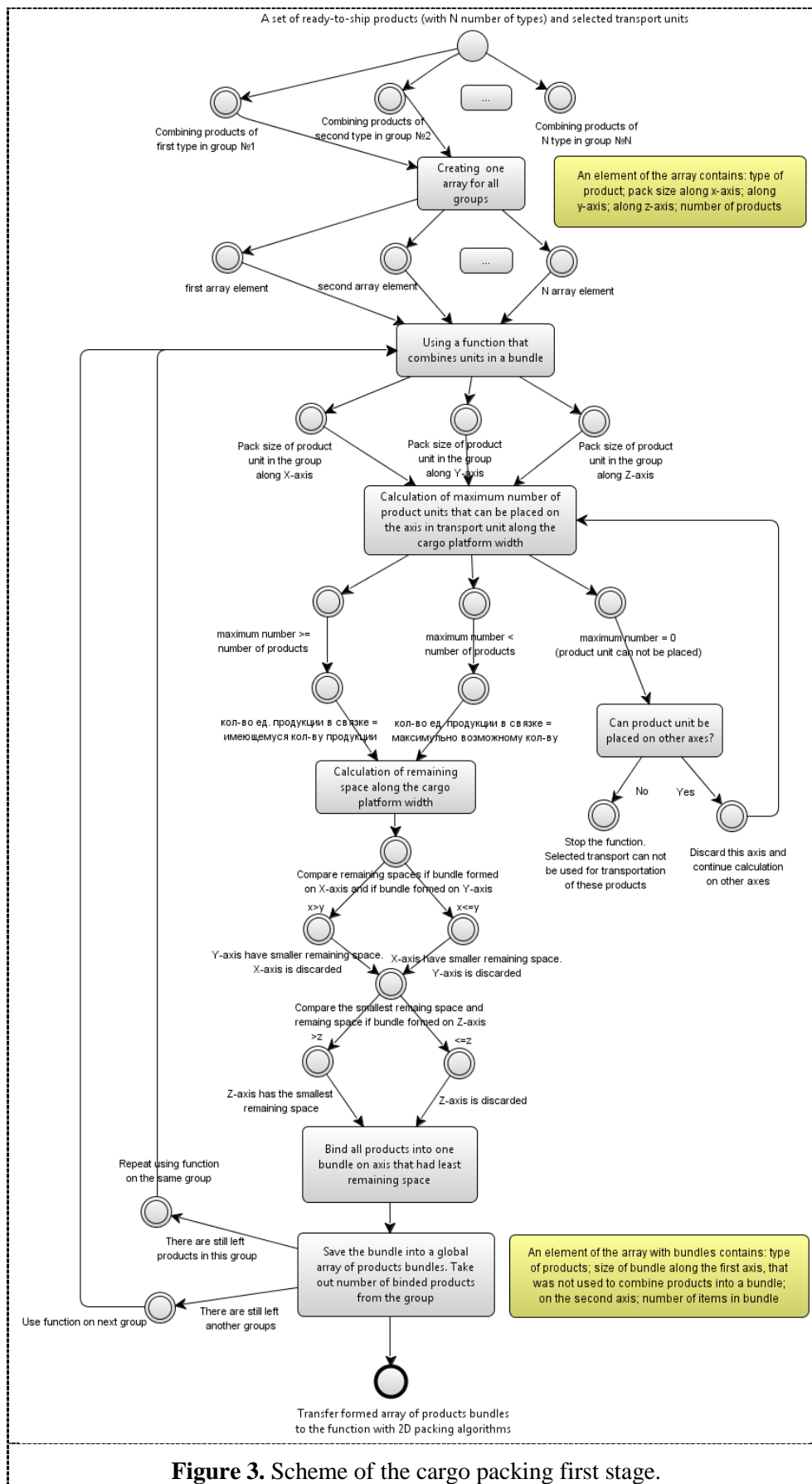
Input data includes orders that containing a list of ordered products, and transport units. We got ready to deliver products from selected orders and free trucks from transport units. Before proceeding to cargo packing we need to compare total weight of cargo to carrying capacity of selected truck [9]. Then there is comparison of cargo total size with size of the cargo platform.

Selected products and transport unit are used as input data for the first stage of cargo packing. Products of the same type are grouped together. All groups are placed in an array. In this way, we get an array, elements of which contain data: type of product; product unit sizes (on three axes); number of products. All axes of each element in the array are used, one after another, in function that calculates how many product units along this axis in a row will fit into selected transport unit along of its cargo platform width. Output data of this function is a bundle of the same type products and parameters of this bundle are: number of product units in the bundle; remain width of the cargo platform, which have not been taken by bundle. For further work, a bundle is selected that uses axis along which remain width of the cargo platform will be the smallest. Selected bundles are added to the array for output data and those product units that are left in this bundles are discarded from list of products selected at the start. The process continues until all products units are packed into bundles. At the output we get an array of bundles containing the data: type of product; remain width of the cargo platform; sizes of product unit along two axes that were not used to form the bundle.

Some types of products are fragile details [10]. As future improvement, it is planned to sort bundles of these products types in such a way that as a result they are placed on top of the rest. If it is not possible to load transport unit completely, there is an option to set percentage for maximum cargo weight. Percentage is selected from truck's carrying capacity. According to the updated carrying capacity, products that have already been collected in bundles are checked separately, instead of taking just total weight of all products. Bundles that do not fit in selected percentage of carrying capacity are discharged for the next shipment.

Formed product bundles are used as input data for 2D optimization algorithms. There is no need to use the axis along which bundles were formed, and also the cargo platform width is not used too. Thus, bundles, like 2D objects are placed in the 2D region of the cargo platform (along the length and height). Algorithms of 2D packing Join and Split-Fit work with such input data. Functions that make algorithms work are formed on the server side of application as an extension of BoltCMS content management system using Symfony framework. After requesting this extension via web interface, calculations are run using chosen algorithms.

Received variants of cargo loading (and unloading as well, presented as reverse loading order) are displayed in interface of web application [11] as schematic representation of the cargo platform and products placed inside of it. A choice of variant among proposed ones is left for operator.



5. Conclusions

In presented work, Join and Split-Fit algorithms were used, which are optimization form of basic FFDH algorithm. Split-Fit algorithm effectively works for packing of large loads, and Join is useful for packing a lot of small goods.

The solution for optimization problem of cargo packing using 2D optimization method is an element of created system for automation of enterprise logistics processes. Algorithms used to create described software will be tested on real examples with enterprise representatives.

In case of successful approbation of this semi-automatic variant (with a choice of optimal scheme by operator), it is possible to switch completely to one of the algorithms if it proves itself to be stably the best. This will fully automate the process of cargo packing.

6. References

- [1] Daeki K, Barnhart C, Ware K and Reinhardt G 1999 Multimodal express package delivery: A service network design application *Transportation Science* **33** 391-407
- [2] Aksyonov K, Bykov E, Aksyonova O, Goncharova N and Nevolina A 2015 Perspectives of Modeling in Metallurgical Production (WIP) 2015 Summer Simulation Multi-Conference SummerSim'15 (Chicago) vol **47** (San Diego: The Society for Modeling & Simulation International) pp 341-344
- [3] Correcher J F, Alonso M T, Parreño F and Alvarez-Valdes R 2017 Solving a large multicontainer loading problem in the car manufacturing industry *Computers and Operations Research* **82** pp 139-152
- [4] Elhedhli S, Gzara F and Yan Y F 2017 A MIP-based slicing heuristic for three-dimensional bin packing *Optimization Letters* **11** pp 1547-1563
- [5] Han X, Chin F Y L, Ting H F, Zhang G C and Zhang Y 2011 A New Upper Bound 2.5545 on 2D Online Bin Packing *ACM Transactions on Algorithms* pp 1-18
- [6] Martello S, Monaci M and Vigo D 2003 An exact approach to the strip-packing problem *INFORMS Journal on Computing* **15** pp 310-319
- [7] Ntene N and Vuuren J H 2009 A survey and comparison of guillotine heuristics for the 2D oriented offline strip packing problem *Discrete Optimization* **6** pp 174-188
- [8] Filonov S D and Sitnikov I O 2017 Developing logistics optimization software for manufactory using computer modeling methods *4th International Young Scientists Conference on Information Technologies, Telecommunications and Control Systems, ITTCS 2017 (Yekaterinburg)* vol 2035 (Aachen: CEUR workshop proceedings) pp. 6-11
- [9] Costa M G and Captivo M E 2016 Weight distribution in container loading: A case study *International Transactions in Operational Research* **23** pp 239-263
- [10] Singh P, Singh J, Antle J, Topper E and Grewal G 2014 Load Securement and Packaging Methods to Reduce Risk of Damage and Personal Injury for Cargo Freight in Truck, Container and Intermodal Shipments *Journal of Applied Packaging* **6** pp 47-61
- [11] Fabio B, Francesco C, Ornella P, Roberto M, Maurizio M, Francesco R and Venuto G 2008 A Web3D application for the bin-packing problem *20th European Modeling and Simulation Symposium (Amantea)* pp. 134-139

Acknowledgments

The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0006.